SINCE the enthalpy change does NOT depend on path, this means that we can use standard values for enthalpy to predict the heat change in reactions that we have not tested in a calorimeter.

THERMOCHEMICAL EQUATIONS

- is like a regular chemical equation, except that phase labels are REQUIRED and the enthalpy for the reaction is given along with the equation.

$$CH_3COCH_3(\ell) + 4O_2(g) \longrightarrow 3CO_2(g) + 3H_2O(\ell) \; ; \Delta H = -1800 \text{ kJ}$$

- Why are phase labels required? Because phase changes either absorb or release energy.

$\Delta H = -1800 \text{ kJ}$ ... what does this mean?

$$1 \text{ mol } CH_3COCH_3 = -1800 \text{ kJ}$$

$$4 \text{ mol } O_2 = -1800 \text{ kJ}$$

$$3 \text{ mol } CO_2 = -1800 \text{ kJ}$$

$$3 \text{ mol } H_2O = -1800 \text{ kJ}$$

We treat the enthalpy change as if it's another product of the reaction!

$$CH_3 CO CH_3 (l) + 4O_2(g) \longrightarrow 3 CO_2 (g) + 3 H_2O(l) \; ; \Delta H = -1800 \, kJ$$

What would be the enthapy change when 25 g of water are produced by the reaction?

1 - Convert 25 g water to moles water. Use FORMULA WEIGHT.
2 - Convert moles water to enthalpy change. Use THERMOCHEMICAL EQUATION

① H_2O : $18.016_g \, H_2O = mol \, H_2O$ |② $3 \, mol \, H_2O = -1800 \, kJ$

①

$$25_g \, H_2O \times \frac{mol \, H_2O}{18.016_g \, H_2O} \times \frac{-1800 \, kJ}{3 \, mol \, H_2O} = \boxed{-830 \, kJ}$$

... also equals Q (heat)
at constant pressure.

This is an EXOTHERMIC process (negative value for enthalpy change/heat). Energy is transferred from the system (the reaction) to the surroundings.

(Not surprising ... this is a COMBUSTION reaction!)

A few more terms related to enthalpy:

- Enthalpy of vaporization / heat of vaporization: The enthalpy change on vaporizing one mole of a substance. (from liquid to vapor)

- Enthalpy of fusion / heat of fusion: The enthalpy change when a mole of liquid changes to the solid state.

Phase changes require energy, too!

Example problems:

FORMULA WEIGHTS in g/mol in purple

$$2 H_2(g) + O_2(g) \longrightarrow 2 H_2O(g) \; ; \; \Delta H = -484 \text{ kJ}$$

2.016   32.00   18.02
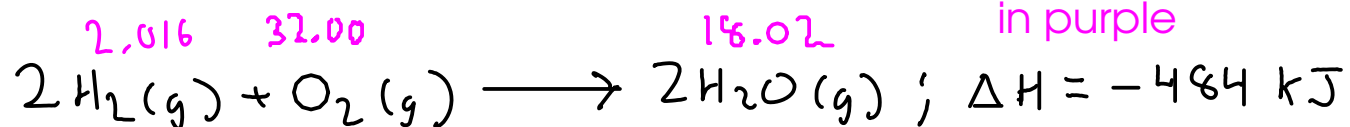
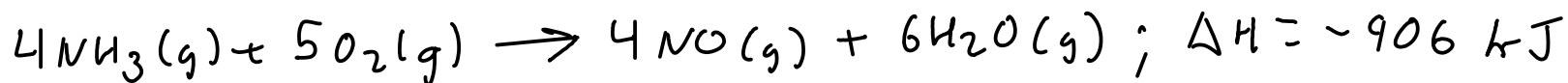Calculate the enthalpy change for the combustion of 1.00 kg of hydrogen gas.

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1 - Convert 1.00 kg hydrogen gas to moles. Use FORMULA WEIGHT.
2 - Convert moles hydrogen gas to enthalpy change. Use THERMOCHEMICAL EQUATION.

① $2.016 \text{ g } H_2 = \text{mol } H_2$ $kg = 10^3 \text{ g}$

② $2 \text{ mol } H_2 = -484 \text{ kJ}$

$$1.00 \text{ kg } H_2 \times \frac{10^3 \text{ g}}{kg} \times \frac{\text{mol } H_2}{2.016 \text{ g } H_2} \times \frac{-484 \text{ kJ}}{2 \text{ mol } H_2} = \boxed{-120000 \text{ kJ per kg } H_2}$$

$4 NH_3 (g) + 5 O_2 (g) \longrightarrow 4 NO (g) + 6 H_2O (g) \; ; \; \Delta H = \sim 906 \, kJ$

What is the enthalpy change when 150. L of nitrogen monoxide are formed by this reaction at 25.0 C and 1.50 atm pressure?

1 - Convert 150. L NO to moles. Use IDEAL GAS EQUATION.
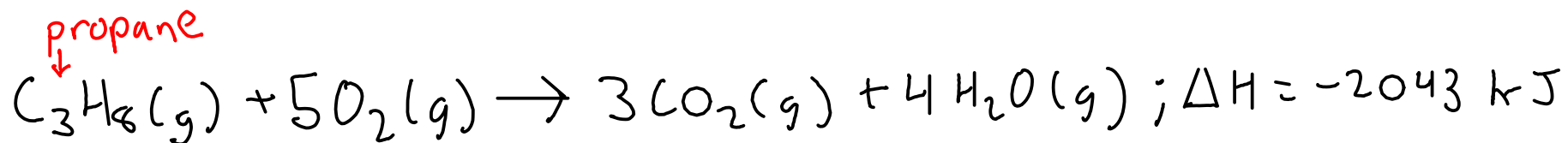2 - Convert moles NO to enthalpy change. Use THERMOCHEMICAL EQUATION.

① $PV = nRT$ | $P = 1.50 \, atm \quad V = 150. L \quad R = 0.08206 \dfrac{L \cdot atm}{mol \cdot K}$

$n = \dfrac{PV}{RT}$ | $T = 25.0 \,^\circ C = 298.2 \, K$

$$n_{NO} = \frac{(1.50 \, atm)(150. L)}{\left(0.08206 \dfrac{L \cdot atm}{mol \cdot K}\right)(298.2 \, K)} = 9.194822849 \, mol \, NO$$

② $4 \, mol \, NO = \sim 906 \, kJ$

$$9.194822849 \, mol \, NO \times \frac{-906 \, kJ}{4 \, mol \, NO} = \boxed{-2080 \, kJ}$$

propane
↓
$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g) \; ; \; \Delta H = -2043 \text{ kJ}$$

Calculate the volume of propane gas at 25.0 C and 1.08 atm required to provide 565 kJ of heat using the reaction above.

1 - Convert energy requirement to moles propane. Use THERMOCHEMICAL EQUATION.
2 - Convert moles propane to volume using IDEAL GAS EQUATION.

① $\text{mol } C_3H_8 = -2043 \text{ kJ}$ Since the SYSTEM is the reaction, the energy requirement has a NEGATIVE sign. The reaction will be losing energy to provide the energy to us!

$$-565 \text{ kJ} \times \frac{\text{mol } C_3H_8}{-2043 \text{ kJ}} = 0.2765540671 \text{ mol } C_3H_8$$

② $PV = nRT$ | $P = 1.08 \text{ atm}$ $T = 25.0\,°C = 298.2 \text{ k}$

$V = \dfrac{nRT}{P}$ | $n = 0.2765540671 \text{ mol } C_3H_8$

$R = 0.08206 \dfrac{L \cdot atm}{mol \cdot k}$

$$V = \frac{(0.2765540671 \text{ mol } C_3H_8)\left(0.08206 \frac{L \cdot atm}{mol \cdot k}\right)(298.2 k)}{(1.08 \text{ atm})} =$$

$$= \boxed{6.27 \text{ L } C_3H_8 \text{ at } 25.0\,°C + 1.08 \text{ atm}}$$